Lee (F. S.) With the compliments of the author.

Studies from the Department of Physiology of Columbia College. Vol. 1.

THE SCOPE OF MODERN PHYSIOLOGY

—BY—

FREDERIC S. LEE.

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presented by the author

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By Frederic S. Lee.

A review of the present aspect and tendency of a rapidly growing science in the light of its history may not be without profit. It may help to clearer vision and more exact orientation; and it may direct and stimulate investigators. These thoughts, together with the prevalence of an apparent misconception regarding the true aim and scope of Physiology, have led to the following paper.

To one who is acquainted with modern biology, it will seem unnecessary to repeat that physiology is the science of function or action; that it is to be contrasted with morphology, the science of form or structure; that these two form the grand divisions of the science of living things, or biology; that, just as there is an animal and a vegetable biology, so there is an animal physiology and a vegetable physiology; that, further, every species has its physiology; that every portion of living matter, be it organism, organ, tissue, cell, or simplest group of molecules deserving the name protoplasm, Weismann's biophor, has its physiology; that, for whatever functions or acts, there must be possible a science of function or action. All this seems self-evident and trite to the biologist. By the non-biologist its truth is being overlooked constantly. To him, forgetting that botany and zoology exist, the term physiology means merely *human* physiology, a most narrow significance and one that is productive of evil results. Undoubtedly the animal physiologists themselves have been responsible, unintentionally and unwittingly, for this common and radically false notion of the relatively narrow field of their science. In their zeal to penetrate the mysteries of that most wonderful and most interesting of all protoplasmic structures, the human body, and in their desire to perfect a strong foundation

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for the science and art of medicine, it was to be expected that their investigations should have an "anthropocentric" bias and that physiology and medicine should be born and grow old together. Let a union so intimate be once established, let centuries of tradition surround and strengthen it and the separation is not an easy process. With special reference to this question and at the risk of treading upon well-known historic ground, what has been in brief the history of animal physiology?

It is convenient to divide it with Preyer into five periods; the first four ending approximately with the dates 350 B. C., 160 A. D., 1628, and 1837 respectively, the fifth extending to the present time. The last four periods are characterized by one or more prominent investigators, the second by Aristotle, the third by Galen, the fourth by Harvey and Haller, the fifth by Johannes Müller.

The beginnings of animal physiology were contemporaneous with the speculations of the earliest natural philosophers and the labors of the earliest physicians. In Egypt, in China, in India, in Greece, the origins of the science are necessarily indefinite and, with the help of occasional fragments of historical fact, must be left to our imagination. The inclination toward self-study is an innate human characteristic and the more obvious facts of man's bodily functions could scarcely have failed of notice. Something was doubtless learned from the bodies of men killed or wounded in battle, and from the slaughter of animals for food. More precise observations were made upon sacrificial animals for purposes of divination. But facts thus obtained were necessarily isolated, and abundant speculation was the distinguishing characteristic of the whole period. From its shadowy beginnings down to the death of Hippocrates and Plato, the theories that were held regarding the origin and nature of life, unsupported, as they were, by observation and experiment, could not establish a science of vital action. Even Hippocrates himself, skillful as he was in the treatment of diseases, was no physiologist.

At the beginning of the second period was Aristotle, the first systematic observer of natural phenomena. His knowl-

edge of physiological fact was derived, as is well known, in greatest part from his own observations on man, the lower animals, and plants; and to a large extent it forms the basis of all subsequent development of the science. His pupil, Theophrastus, founded the science of vegetable physiology. Contemporaneous with Theophratus was the development of the great school of medicine at Alexandria, and here, under Herophilus and Erasistratus, animal physiology, along with anatomy and pathology, as a part of medicine undoubtedly made great progress. The extent of that progress can be inferred only imperfectly from later writers. The loss of the Alexandrian records is most lamentable. Aristotle had dissected animals; the Alexandrians dissected the human body and, more important for our science if true, it is possible that they performed experiments on animals. The facts made known by Aristotle were added to; physiological material accumulated. Thus, while the first period had been speculative, the second was descriptive. But not yet was there a *science* of function.

Then came Galen, the great physician, investigator, and writer, and it was he who organized the mass of knowledge that through the centuries had been growing. From Galen's time animal physiology has had a recognized position as a branch of natural science. A modern writer[2] says of him: "In the midst of contending factions he alone and for the first time shaped physiology into an independent science. He established physiology as the doctrine of the use of organs; he experimented upon animals * * *; and he suggested questions which he answered by the aid of such experiments. In opposition to all his predecessors and contemporaries, he maintained physiology to be the foundation of medicine. Further, he, first of all and so far as it was possible at his time, described and explained the functions methodically and completely. Upon the one side he sought to refer vital phenomena to natural causes, and upon the other he lauded their purposeful character, with expressions of admiration for the wisdom of the Creator, while their fitness aided him in explain-

[2]Preyer, *Allgemeine Physiologie.*

ing them. * * * The fact that the Galenic physiology, whereever it was known, prevailed for fifteen hundred years is due to its two-sided development. For physicians accepted it because of its materialism, and the clergy because of its teleology. Since Galen was an extraordinarily sagacious thinker, an uncommonly learned man, an industrious, systematic, truth-loving worker and skillful physician, never neglecting practice for research nor research for practice, of all the medical fraternity he seemed best fitted to lay the corner-stone of physiology as a science in itself. And it testifies to his genius that, in the whole thousand years following him, Galen's physiological system, constructed through his originality and the power of his logic, endured as law, seriously opposed by no one. The history of no science can show the like. Faith in the authority of Galen's name finds its equal only in the history of religions." It is to Galen's influence, doubtless, more than to that of any other, that the intimate union of physiology and medicine, continuing even to the present day, is due. And to him likewise we must ascribe the present prevailing idea, already spoken of, of the essentially human character of the science. Galen's physiology was in essence a human physiology; and the new science fully born became the handmaid of medicine. Galen's authority was supreme until the age of the Renaissance, and throughout the long mediaeval period animal physiology was at a standstill. Toward its close the Italian universities were established and men began to think for themselves, to read nature in addition to the books, and gradually to learn that nature and Galen did not always agree. The elaborate and ill-founded hypotheses of the spirits, the elements, the qualities, and the humours did not accord with the progressive, investigating spirit of the Renaissance and rebellion against the master gradually grew in strength. Paracelsus burned in public at Basel the works of Galen. More destructive than fire were the anatomical investigations of Vesalius and Fallopius. And in physiology Colombo and Caesalpinus prepared the way for the most important single discovery of the times. This event, which more than all else demonstrated the ineffectiveness of pure speculation and the

need of a rational method of observation and experiment, was none other than the discovery of the circulation of the blood.

With the announcement of this to the world in 1628, what we have called the fourth period of physiological history begins. Harvey's book, "*De Motu Cordis*," is a model record of an ideal scientific investigation. The accumulation of an abundance of the essential facts, obtained by a most careful and systematic study of nature, the clear understanding of their logical positions and their mutual relations, and then, unhampered by scholastic systems and *a priori* considerations, but guided only by a regard for truth, the orderly arrangement of the accumulated material into the one possible rational system—such was Harvey's method. The result was incontrovertible. The full title of Harvey's work is "*Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus*," but Harvey himself, being a physician, and his contemporaries and followers naturally enough considered more especially the human bearings of the established facts. For two hundred years after, discovery followed discovery, and the permanent foundations of the various subdivisions of physiology were laid—circulation, respiration, animal heat, the functions of the central nervous system and of the peripheral nerves, movement, animal electricity, reproduction, optics and acoustics. Haller's well-known contribution was that of the independent irritability of muscle. Of perhaps as much value were his complete knowledge of physiological literature and his activity in writing. In 1747 he published a text-book, the "*Primae Lineae Physiologiae*," and in 1757 the large and complete "*Elementa Physiologiae Corporis Humani*." These books were widely circulated and the entity of the science was forever established. The title of Haller's larger work, "Elements of the Physiology of the Human Body," indicates that its "anthropocentric" character was stamped firmly upon it. By its independent growth, its subordination to medicine was, however, already weakened.

To enumerate its advances during the past fifty-six years, the fifth period, would be a task of great proportions. The

man to whom it is customary to give the credit for having outlined the path that was to be followed during his lifetime and for the generation that has elapsed since his death, the teacher, either personally or by his writings, of the veterans, Ludwig, Du Bois Reymond, Brücke and Helmholtz, was Johannes Müller. Müller's name will at once suggest the one important principle that he formulated, that of specific nerve energies, but his writings and discoveries cover a wide field. His extraordinary knowledge, energy, enthusiasm and stimulating power were all-important during a period so rich with biological achievements. It is perhaps a fair question, whether Magendie, with his marvellous activity as an experimentalist, may not dispute with Müller the honor of having given to the physiology of the past fifty years its characteristic trend. Certain it is that he fathered the science in France (Claude Bernard was his pupil); that his writings were read much across the Rhine; and that the labors of the Germans have been, like his, the collecting of facts rather than the constructing of systems. Within this half-century the establishing of the two great doctrines of physics, the mechanical theory of heat and its greater corollary, the conservation of energy, were of indispensable aid to the development of physiology. The idea of vital force had taken on many forms and the controlling principle of life had played its part under many titles. But, when it was shown that in the inorganic world the various kinds of energy are mutually interchangeable, physiologists, long hampered by and impatient under the old ideas, eagerly siezed upon the new, in fact, aided not a little in their discovery, and proved that they applied to living things as well as to the not-living—and, with this, freedom from unscientific speculation was won; the animal is a machine in a sense more complete than the Cartesian one. On the purely physiological side of biology, this is undoubtedly the greatest achievement of the present century. Until the substance of the plant and the animal body could be regarded as subject to the same laws that controlled all other matter, much must have remained mysterious and inexplicable and physiology could not be reckoned as all in all a

natural science. Psychology has always been hampered by the speculations of the system-loving metaphysicians. More actual fact and less conjecture are essential to the scientific method; and the scientific method is the method of progress. Following this freedom from the doctrine of vital force, physiology has developed actively along two main lines, the chemical and the physical including the mechanical, and is now often defined as the chemistry and the physics of living matter. An astonishing number of discoveries have been made, and the outlines that were sketched by Galen and Harvey and Haller and Müller and Magendie have been filled in with remarkable rapidity and completeness.

Let us consider for a moment the prominent characteristics of the work of this period. In the first place, Vertebrates have received more attention and have been the subject of more systematic investigation than Invertebrates. And among the Vertebrates, with the exception of the indispensable frog, which, however, is rarely regarded as a finality in research, the Mammals, being nearest to man have been most studied. Second, the number of forms used is very small; it is probably safe to say that the genera employed in four-fifths of the researches could be counted easily upon the fingers of the two hands. Third, adult animals have been used almost exclusively. Fourth, the study of organs has prevailed, i. e., the investigator has endeavored to discover the chemical, physical and mechanical laws by which the heart, the lungs, the glands, the muscles and the brain perform their respective tasks. These characteristics are the natural outcome of the birth and growth of the science. They indicate that, although the results accomplished are widespread and of the greatest value, there are left almost untouched still wider fields. The achievement of so much, however, along the lines of the past is stimulating to the student of to-day, for it has made possible the more rapid development of the science in the new directions, in which it is now tending. To these we shall return shortly.

I think that the historian of the present period will not fail to be struck by the comparative paucity of hypothesis in

physiological research, especially when our science is contrasted with the other great division of biology. It is as if men had been nauseated by the vitalistic doctrines and other wild guesses of the past and had resolved hereafter to hold strictly to the Baconian method. At the risk of being misunderstood and criticised, I cannot help feeling that this is to be deplored. The method of all physical science is truly observation and experiment; facts must be discovered and grouped and the laws formulated therefrom. But, in the search after facts, the inestimable value of hypothesis—of speculation, if you will—cannot be denied. It directs the searcher along a definite path and gives for the time being an encouraging and stimulating coherence to his results. If later his speculation becomes verified, well; if it proves false, its use is not to be deprecated, for it has served its purpose as an aid to discovery. The facts still remain, science is by so much the gainer, and with a new interpretation and a new hypothesis nearer the truth further advance will be made. The trouble is to keep the speculation within rational bounds and to know when to give it up. To employ it too sparingly is to retard scientific progress, and it seems to me that just here the animal physiologists of the present period are open to criticism.

Further, it is to be noted that until far into this period throughout the Continental, the English, and most of the American universities physiology and anatomy have together formed one department. At Bonn from 1826 to 1833, and at Berlin from 1833 until his death in 1858, Müller occupied such a common chair. Helmholtz held a similar position in Bonn from 1855 until 1858. Now, everywhere, animal physiology presupposes anatomy, and each science has its own field and its own methods. Further still, physiology usually occupies a place in the Medical faculty. This also is the result of its historical development. As I have shown, it is to the medical fraternity, more than to any other one class, that it owes its great progress in the past. But a glance at the literature of the present period will show that, largely through the efforts of its medical promoters, it has widely overstepped its early

medical boundaries. It has long since ceased to be a purely medical and anthropological science; it has become a biological science. Human physiology, like human anatomy, will necessarily always form one of the foundation stones of a medical training, and perhaps the most important one. But human physiology is but one branch of a science as broad as are the domains of protoplasm. Man's body is a machine, but it is a machine that has had a history. It is an achievement to learn to know the mechanical, chemical, and physical laws of this most complex of vital mechanisms. But the task of the physiologist does not end here—I should say it does not begin here. To know the action of the mechanism without its history is not only short-sighted, it is impossible. This is being recognized and a school of general and comparative physiologists is arising. During the present period, then, beside its great advance along the older lines, our science has begun a development along broader biological paths. It has won a place as an independent, pure natural science. More and more are its claims to admission to Pure Science and Philosophical faculties being recognized. It should be placed and will be placed by the side of chemistry, physics, and the morphological division of biology. I do not think it an exaggerated statement, that the tendency of biological thought at present is toward extraordinary activity along physiological lines.

(*To be continued.*)

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Three achievements of the present period have shown investigators how broad their science really is. First, the establishing of protoplasm as the physical basis of life, and of its substantial identity in plants and animals by Dujardin, Von Mohl, and Max Schultze, showed that the really fundamental problems of life and action had heretofore not been grasped; that the essential laws of protoplasmic activity apply to the whole organic world; and hence that any physiology which confines itself rigidly to either plants or animals to the exclusion of the other is a one-sided science. Second, the cell-theory of Schleiden and Schwann demonstrated that sooner or later many functions must be traced back to the cell, and that a cellular physiology is the key to a large proportion of the problems arising in the biological world. Third, the work of Darwin, based, as it was, upon physiological principles, showed that the action of the environment upon the individual and upon the species, as well as the action of the organism upon the environment, was an almost unworked field of the richest promise; that all physiology, in order to be complete, must be comparative; that there is an ontogenetic and a phylogenetic evolution of function; and that the physiological laws of heredity were yet to be discovered.

Let us examine these ideas briefly. The necessity of understanding the physiology of undifferentiated protoplasm is obvious, for there we find function in its simplest and most generic form. The phenomena of projection and retraction of pseudopodia in the Amoeba are doubtless the key to the complex processes of contraction and relaxation of striped muscular tissue. It is not at all improbable that the action of light upon the retina is a specialized derivative of the heliotropic phenomena of the simplest plants and animals. Four years

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ago, the well-known Oxford physiologist, Burdon Sanderson, wrote concerning the nature of physiological inquiry, "The work of investigating the special functions, which, during the last two decades, has yielded such splendid results, is still proceeding, and every year new ground is being broken and new and fruitful lines of experimental inquiry are being opened up: but the further the physiologist advances in this work of analysis and differentiation, the more frequently does he find his attention arrested by deeper questions relating to the essential endowments of living matter, of which even the most highly differentiated functions of the animal or the plant organism are the outcome." Again, "No one who is awake to tendencies of thought and work in physiology, can fail to have observed that the best minds are directed with more concentration than ever before to those questions which relate to the elementary endowments of living matter, and that if they are still held in the background, it is rather because of the extreme difficulty of approaching them than from any want of appreciation of their importance. * * * * If we really understood them, they would furnish a key, not only to the phenomena of nutrition and growth, but even to those of reproduction and development. * * * * It is in the direction of elementary physiology, which means nothing more than the study of the endowments of living material, that the advance of the next twenty years will be made."

Regarding the need of a cellular physiology, it is only necessary to review our knowledge of any one of the complicated organs to perceive that aside from the principles, often chiefly mechanical, involved in the work of the organ as a whole, the essence of its activity lies in the activity of its component cells. The work of the muscle, *e. g.*, is the sum of the activities of its constituent physiologically similar fibres. A single gland cell illustrates the principles of secretion as well as, or even better than, a thousand grouped together into a compact gland. The complexity of brain operations is due to the complexity of brain structure, but the active agents are the comparatively simple nerve-cells. Huxley sets forth as the first three of the five chief ends of modern physiology: "Firstly, the ascertain-

ment of the facts and conditions of cell-life in general. Secondly, in composite organisms, the analysis of the functions of organs into those of the cells of which they are composed. Thirdly, the explication of the processes by which this local cell-life is directly, or indirectly, controlled and brought into relation with the life of the rest of the cells which compose the organism." Now that the structure of protoplasm is fast becoming disentangled, a rational cell-physiology will be possible. In urging the need of investigating cell-function, I do not mean to imply that the cell is necessarily the ultimate unit, and that the organism is to be regarded as substantially a colony of physiologically independent cells. Much of the recent cytological work indicates that ere long the cell may be deposed from its hierarchical position.[1] Cellular interactions are to form an increasingly prominent place in the researches of cell-physiologists. But, whether or not we grant with many that the cell is of secondary significance, we must allow that, in many respects at least, it may be regarded as a physiological unit; and from this standpoint it demands investigation.

In these days of comparative science, it seems superfluous to urge the necessity of a comparative physiology. No one, who thinks seriously of the matter, will doubt that along with the morphological distinctions between different species, genera, orders, or classes, and even in cases where gross morphological distinctions are not apparent, there must be physiological differences. Beyond the obvious facts of simple observation, these are almost wholly uninvestigated. De Varigny, in his suggestive little book on Experimental Evolution, has collected a number of the known facts. In a garden in the south of France, were growing, side by side, a number of plants of the same species. There appeared to be no morphological differences between them, but some were indigenous to the soil in which they were growing, while others had been imported from the Canary Islands. When they were attacked by frost, all the Canary Island forms perished, while the French forms were untouched. There was evidently some obscure physiological difference between them. The two common European species

[1] Cf. Whitman, *Journal of Morphology*, VIII, No 3, August, 1893.

of frogs, *Rana temporaria* and *Rana esculenta*, behave very differently toward certain drugs, as Schmiedeberg, Monnier, Vulpian, Harnack and Meyer, and others have shown. In *R. temporaria*, caffeine causes a decrease in excitability; in *R. esculenta* an increase; in *R. temporaria* pilocarpine causes paralysis; in *R. esculenta* tetanus. The venom of one snake is harmless for its own species, but poisonous for others. The spinal cord of the fish is differently endowed from that of the frog, though the differences have never been properly investigated. The muscle of the Insect is far removed functionally from that of the Crustacean, though how far remains to be discovered. I do not overlook the fact that already much excellent work upon the physiology of the Invertebrates and lower Vertebrates has been done, but too often such work has not been *comparative*. Fitness for the object of the research is the usual determinant of choice—and hence the frog has taught us most of our physiology of muscle. Sooner or later this must all be changed, the functional differences must be made known, and the exact position of each plant, each Invertebrate, and each Vertebrate, in the physiological series, together with the exact position of his organs and tissues and cells must be understood. For we must recognize the fact that function in any one species has *come to be*—an evolution of function is as much a reality as an evolution of form. The adult body and its organs, tissues and cells are the functional derivatives of the germ-cells—in the growth of the individual there has been a physiological ontogeny. So in the growth of the species there has been a progressive or retrogressive development of function: and one of the most attractive fields for our future work will be the tracing out of the phylogeny of function, now a practically unknown subject.[2] The difficulty of such an undertaking is great, for the rich palaeontological series is beyond the reach of the experimentalist. Yet this should be no bar to the systematic investigation of existing forms. Such a phylogeny will vary with each functional part (organ, tissue or cell): *e. g.*, if, in one genus, certain brain functions and certain secretory functions are always found, the presence of the same brain

[2] Cf. Dohrn, *Das Princip des Functionswechsels.*

functions in another genus does not necessarily indicate the presence of the same secretory functions. Nor will the line of functional descent of a part necessarily coincide with the line of morphological descent of the organism. A natural system of classification is based and, justly so, on morphological considerations. In thus tracing out the genetic relationships of function, lie the attractiveness and the utility of the comparative method in physiology. And I venture to assert that, if all investigators would bear in mind the fact of an evolution of function, surprising advances would result in our knowledge of the working of adult organs.

What is it that makes an individual physiologically what he is? There are two agents—heredity and the environment. As to heredity, the active discussion now going on around Weismann as a centre, serves to show what a vast amount we do not know, on both the morphological and the physiological sides as regards the general phenomena of heredity and the nature and behaviour of the hereditary substance. No one recognizes this more fully than Weismann himself. He confesses that his own theory is far from complete; that its importance consists primarily in its suggestiveness; that the real solution of the problem lies in the future, and that facts are greatly needed. In this connection I may refer to the value of the work of Nussbaum, Gruber, Balbiani, Hofer, Korschelt, Verworn and others on the physiological relations of the nucleus and cytoplasm.

The mutual relations of the environment and the individual are almost as unknown as when Darwin first demonstrated their importance. In a few special lines they have been investigated. In his earthworm studies Darwin himself set an eminent example. The fact of the modification of the virulence of pathogenic bacteria by their treatment during growth is well known. Interesting results have been obtained regarding the action of salt-water on fresh-water animals, and *vice versa*; the action of salts on starch production in plants; the effect of depriving animals of apparently important salts, *e. g.*, fowls of carbonate of lime, and crabs of calcium chloride. Maupas's well-known studies on the influence of temperature on

the determination of sex may be mentioned here, as well as those of Yung, Mrs. Treat, and others on the influence of foods. If an altered environment is capable of altering function—and we know this to be a fact—and if the altered function reacts upon structure—which is equally undoubted—then we find in these premises sufficient justification for searching after the facts concerning the nature and extent of environmental influence. The value of such researches lies not so much in the isolated results themselves, as in the fact that such results, when sufficiently numerous, will lead us directly not only to a better understanding of the internal physiology of organisms, but, what is of more general interest, to an understanding of the causes of variation, and thus to a better comprehension of the relations of species to one another. Too much cannot be said upon this phase of our subject. Whether the direct action of the environment is to be considered as a factor in organic evolution or not, the causes of variation must be investigated *experimentally*, and the physiological side of the work must not be neglected. Semper says, "Although the morphological section of animal biology[3] teaches with much probability that this species or that organ has undergone this or that course of modification in the animal series, and that in the process of modification it has passed through a whole series of various forms, still it is only physiological research that can elucidate the necessity for their existence by revealing their causative conditions."

One word regarding the relations of physiology and morphology. In the broad way in which I have outlined the former science, it may be charged that I have trespassed upon the morphological preserve. I do not deny the charge. It seems to me altogether unnecessary, undesirable and moreover impossible to draw a sharp line of distinction between the two sciences. With a common origin, mutual independence was, in time, necessary to the growth of each, yet this is in entire harmony with the fact that they have a common meeting-ground. In these days, as always, the morphologist must be something of a physiologist; the physiologist something of a

[3]He might justly have omitted the word "animal."

morphologist. The current researches and discussions on evolution, heredity, and other fundamental questions make this constantly more evident. Like zoology and botany, each has its special field of labor, its special methods, and its special problems; but the fields are constantly overlapping, the one learns methods from the other, and the ultimate problems of both are the same.

Let us now draw together the main lines of our thesis. I prefer to conceive of physiology as the science of the dynamics of living matter. Its tasks for the future seem to comprise the following classes of investigations.

First, the functions of adult organs, tissues and cells in plants, Invertebrates and Vertebrates. The greatest interest at present appears to center about the phenomena of heredity, the central nervous system, and general cell physiology. Second, the ontogeny of functions, or embryological physiology. Third, the phylogeny of functions. Fourth, the physiology of organisms, comprising the mutual relations of organisms to each other and to their environment.

It would be superfluous here to discriminate between the opportunities for research offered in these four classes of problems. Each covers a wide field of rich promise. Each is largely unworked—in reality, as we have shown, research in the past has been confined almost wholly to the first group. Each will lead the investigator to fundamental problems.

In considering these tasks it will be perceived that I have viewed the organism in two aspects, in its internal and its external relations. The problems of the first three groups may be regarded as belonging to *internal physiology*, those of the fourth to *external physiology*. Nearly twenty-five years ago, Haeckel made a similar division into *Conservations-* and *Relations-Physiologie*.[4] Such a classification is convenient and valuable. But it must be remembered that it is artificial, and must not be taken as indicating a fundamental distinction between two sciences. The two are departments of the one science, physiology, and pass the one into the other. For a fact that becomes the more striking, the longer one studies the

[4] *Jenaische Zeitschrift*, V, 1870.

dynamics of living matter, is the utter impossibility of drawing a sharp line between the internal and the external. The functional organism is constantly acted upon by the environment, and is incapable of existence apart from it. But the functional organism is but the *ensemble* of the functional parts, and the parts are linked functionally together, constantly acting and reacting upon each other and modifying each other's work. It follows that the innermost portions cannot free themselves from environmental influence, and the attempt at an essential separation of internal from external physiology is in vain. Nor is such an attempt justified any the more by methods of investigation. For he who studies the action of light upon the retina, is thereby fitted to investigate the heliotropic phenomena of the organism; and he who is familiar with methods by which the effect of salts or temperature on the organs is tested, is most capable of testing the influence of the composition and the temperature of the surrounding water upon aquatic animals and plants. I speak of this the more especially because of the fact that, since the completion of the greater portion of this paper, the able address of Professor Burdon Sanderson, as President of the British Association for the Advancement of Science, has appeared.[5] In an interesting manner Professor Sanderson reviews the aspects of physiology since the time of Müller. He says, "The distinction * * * * between the internal and external relations of plants and animals has, of course, always existed, but has only lately come into such prominence that it divides biologists more or less completely into two camps—on the one hand, those who make it their aim to investigate the actions of the organism and its parts by the accepted methods of physics and chemistry, carrying this investigation as far as the conditions under which each process manifests itself will permit; on the other, those who interest themselves rather in considering the place which each organism occupies, and the part which it plays in the economy of nature. It is apparent that the two lines of inquiry, although they equally relate to what the organism *does*, rather than to what it *is*, and therefore both have

[5] *Nature*, September 14, 1893.

equal right to be included in the one great science of life, or biology, yet lead in directions which are scarcely even parallel." Giving then a somewhat misleading interpretation of Haeckel's ideas above referred to, Professor Sanderson proceeds to divide Biology into three parts, Morphology, Physiology, which deals with the "internal relations of the organism," and Oecology (a term borrowed from Haeckel) "which concerns itself with the external relations of plants and animals to each other, and to the past and present conditions of their existence." In another place, Professor Sanderson says, "No seriously-minded person, however, doubts that organized nature, as it now presents itself to us, has become what it is by a process of gradual perfecting or advancement, brought about by the elimination of those organisms, which failed to obey the fundamental principle of adaptation, which Treviranus indicated. Each step, therefore, in this evolution, is a reaction to external influences, the motive of which is essentially the same as that by which, from moment to moment, the organism governs itself."

I realize how presumptous it appears in me to differ from or attempt to criticise the views of one who occupies so deserved a place among the foremost physiologists of to-day. Yet I cannot repress the thought that the author of the Nottingham address viewed his subject more in the waning light of a day that is ending than in the brightening beams of a coming dawn. If each "step * * * * in this evolution is a reaction to external influences," why should not the student of the "steps" study also the origin and causation of those steps? I think he would justly be open to the charge of narrowness if he did not do it. And, moreover, as I have indicated above, I believe not only that he of all is best fitted, but that a rational view of his science forces him to do it. The progress of a scientific physiology has been greatly retarded by its followers confining themselves too exclusively to "the internal relations of the organism." Not the least of the retarding consequences is the fact that thereby the science loses much of its attractiveness. Just as anatomy, illumined and vivified by the theory of evolution, and broadened by the incorporation of embryol-

ogy and paleontology, became the science of morphology, so I believe that physiology is destined to undergo, and is undergoing, a similar vivifying and broadening process, and is to become the science of vital phenomena, wherever and however they may be exhibited.